OSBORNE Cu-Au DEPOSIT, CLONCURRY, NORTH WEST QUEENSLAND

N. F. Rutherford[1], L. M. Lawrance[2] and G. Sparks[3]

[1]*Rutherford Mineral Resource Consultants, 87 Brook Street, Coogee, NSW 2034,*

[2]*Centre for Global Metallogeny, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009.*

[3]*Placer Pacific (Osborne) Pty Ltd, PO Box 5170MC, Townsville QLD 4810*

LOCATION

The Osborne deposit, formerly Trough Tank, is approximately 195 km SE of Mt Isa at 22°04'S, 140°34'E; Boulia 1:250 000 map sheet (SF54-10).
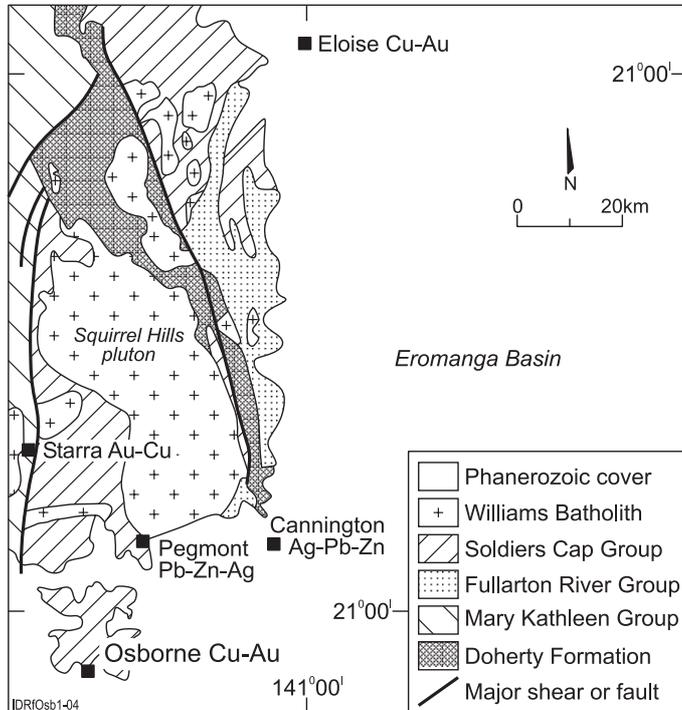
Figure 1. Location of the Osborne Deposit in relation to geology and other deposits (after Adshead et al, 1998).

DISCOVERY HISTORY

A long period of regional exploration for base metals by Newmont, ICI and Dampier Mining in the Selwyn district commenced in 1971 after the discovery of the Pegmont deposit (Adshead *et al.,* 1998). This ultimately led to the discovery of significant Cu-Au mineralization beneath 30-50 m of deeply weathered cover at Osborne in 1989. In 1985, Billiton and CSR formed a joint venture to explore for ironstone-hosted Cu-Au mineralization. Drilling of ironstone, airborne magnetic, IP and ground magnetic anomalies during 1985 to 1987 defined four main ironstone targets (Anderson and Logan, 1992). Placer Pacific Exploration Limited acquired CSR in 1988 and continued intensive drilling of weakly mineralized ironstone at Osborne that led to intersection of 32 m averaging 5.8% Cu and 3.23 g/t Au from 98 m depth. Intense RC and diamond drilling was completed between 1990 and 1993, defining a total measured and indicated mineral resource of 11.2 Mt at 3.51% Cu and 1.49 g/t Au. Mining was initially by open pit into supergene ores (968 000 t) followed by underground mining of high-grade primary ore. Further exploration since 1996 has delineated high-grade primary mineralization dipping steeply E to some 1100 m vertical depth. The total mined, unmined and indicated resources are about 36 Mt at 1.1% Cu and 1 g/t Au (Tullemans *et al.,* 2001).

PHYSICAL FEATURES AND ENVIRONMENT

Osborne is situated in a region of flat to gently undulating plateaux surrounded by alluvial flats, with elevations ranging from 260 mRL to 290 mRL. Breakaways are developed along the margins of the deeper drainages, with silcrete and ferricrete exposed mainly on plateaus. The climate is semi-arid with an average annual rainfall of 320 mm falling mostly in summer. Mean daily minimum and maximum temperatures are 24-39°C (January) and 7-23°C (July); monthly evaporation rates are up to 360 mm in summer, decreasing to about 125 mm in winter.

A eucalypt-spinifex grass-woodland predominates on deep soils; grass with scattered scrub is common within flat, open, soil-filled drainages.

GEOLOGICAL SETTING

The Osborne deposit is hosted by the Proterozoic Soldiers Cap Group (Figure 1) comprising metapelite, metapsammite, quartzite, ironstone, and amphibolite rocks, part of the Mount Norna Quartzite, near the contact with the Llewellyn Creek Formation. Mid-Proterozoic granites and granitic pegmatites intrude the sequence (Blake, 1987; Williams, 1995). The host rocks are unconformably overlain by 30-60 m of Mesozoic marine sediments of the Eromanga Basin. These comprise a basal grit, the Longsite Sandstone, and fine sandstone, mudstone and claystone of the Wilgunya Formation. The upper part of the deposit is near vertical and three mineralized zones subcrop at the Proterozoic-Mesozoic unconformity (Lawrance, 1996).

REGOLITH

The Precambrian metasediments that host the mineralization and the overlying Mesozoic marine sediments are both deeply weathered. The mineralized bodies were weathered prior to burial to siliceous gossan, which sub-crop as a basement topographic high some 20 m above the general elevation of the Mesozoic unconformity. The surrounding basement has been truncated in the lower saprolite. Rounded fluvial pebbles, cobbles and, less commonly, boulders mark the palaeosurface. Subsequent marine incursion and regression during the Mesozoic resulted in deep burial of the basement by reduced sediments. More recent extended sub-aerial exposure has resulted in weathering and oxidation of the upper Mesozoic. A trend towards aridity during the Tertiary and Quaternary, has produced several generations of siliceous and ferruginous duricrusts in the near-surface that mark palaeo- and present drainage valleys (Lawrance, 1996).

The present setting of the Osborne mineralization, beneath an eroding plateau, is summarized schematically in Figure 2. Erosion and slope retreat along the present drainages has exposed older silcrete and the lower weathered profile on the upper parts of the plateau occupied by the mine site, with younger generations of silcrete exposed on lower valley slopes. The inferred oldest preserved silcrete pediment occurs as remnants capping the highest landforms around the pit and original tailings dam. This older surface is undergoing degradation, collapse and dissolution to form a locally transported, ferruginous duricrust that caps the pit area and slopes away from it. A widespread hematitic scree, up to 1 m thick, is derived from erosion of the mottled zone exposed on the upper parts of the plateau. Silica, dissolved from the older silcrete surface and kaolinite in the upper saprolite under arid-phase weathering, is precipitating in the weathered Mesozoic sediments on lower slopes and in the drainage floors. These young pedogenic silcretes occur as sheets beneath thin soil. Silica, precipitated from groundwater, has also silicified the hematitic scree. The youngest silcretes occur as opaline replacements of leached saprolitic clays and as siliceous precipitates at seepage zones at the base of hill slopes adjacent to drainages. At some sites, ferruginous cutans occur on ferruginous lag and other materials (Rutherford, 2002a, b).

The Mesozoic cover is strongly faulted and fractured (Lawrance, 1996). The silcrete and ferruginous duricrust around the pit shows dissolution, collapse and erosion above the orebody. Remnants, seen in the upper walls at the northern and southern ends of the pit, form collapse breccias, accompanied by dissolution and brecciation of silcrete horizons and 'collapse pipes' that penetrate the Mesozoic rocks for several metres including, in some places, intersection with a palaeo-redox horizon.

The distribution of various components of the regolith around Osborne can be seen in normalized radiometric images. Areas dominated by
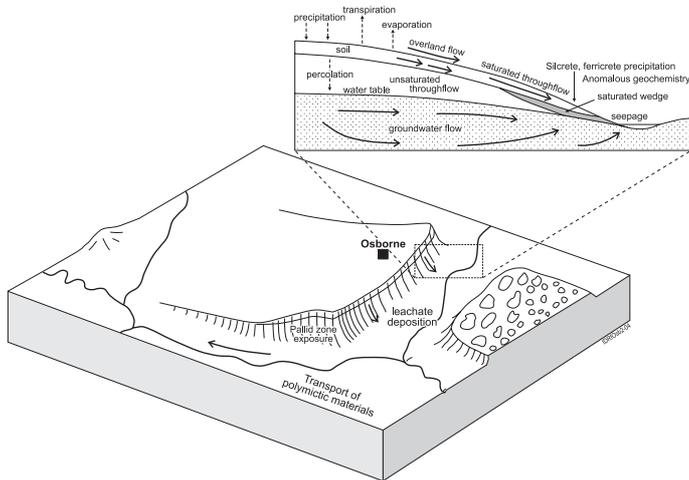
Figure 2. Schematic regolith setting.

exposed silcrete can be separated from areas of leached saprolite and mottled clay, sheet wash, soils and alluvium. There is a higher K (illite) signature from exposed lower saprolite; high Th indicates exposure of ferricrete (Rutherford, 2002b).

MINERALIZATION

Osborne is a structure-hosted silica-magnetite-Cu-Au replacement deposit. Ore minerals are predominantly chalcopyrite and pyrite with pyrrhotite in some parts. The Au is largely free but is closely associated with Cu sulphides. Common gangue minerals include pyrrhotite, pyrite, magnetite, siderite, talc, chlorite and ferropyrosmalite and the minor elements include Ag, Bi, Co, Hg, Mo, Se, Sn, Te, W and F. The mineralization is associated with abundant silica flooding or replacement, accompanied by abundant magnetite alteration, and strong deformation within steeply dipping major thrusts. Sodic metasomatism and hematite are locally well developed. Ore fluids are thought to be high temperature, chemically complex and hypersaline, indicative of a magmatic origin, but retrograde metamorphism cannot be discounted (Adshead, 1995; Adshead *et al.,* 1998 and Tullemans *et al.,* 2001) Recent detailed exploration indicates that Cu-mineralization also occurs away from ironstones within the host structures so the ironstone is not the unique host.

The ore body sub-crops beneath the Precambrian-Mesozoic unconformity as a gossan. A zone of secondary carbonates, mainly malachite and cuprite, overprinted by chrysocolla and minor atacamite and tenorite, 5-10 m thick, separates the gossan from the underlying steeply E-plunging primary sulphides (Lawrance, 1993, 1996; Scott and Meyer, 1993; Adshead, 1995; Tullemans *et al.,* 2001). Siliceous gossanous ironstone pebbles, cobbles and boulders are spread along the unconformity from the ore.

REGOLITH EXPRESSION

Despite the intense weathering of the Mesozoic rocks, erosion and burial of the mineralization, there was a distinct geochemical anomaly for a range of elements (Cu, Bi, Cd, Ge, Hg, Se, Eu, Sm) in soils directly over the open pit site. The most distinctive anomalies were identified by a cold 0.1M HCl leach and from pSirogas analysis. Methods such as BLEG, CHIM, EDTA, weak nitric acid and total extracts, although producing anomalies for some elements, were less effective, giving lower peak to background ratios (Lawrance, 1993; Scott and Meyer, 1993). Analyses of soils, rocks, and pisoliths are given in the Summary Table.

Geochemical traverses across the deposit are very spiky, typical of partial leach extraction in areas of deep weathering and thick cover. The spikes in the surface geochemistry reflect the variable permeability of the sediments. This substrate is controlled by near-vertical fractures that extend through the Mesozoic cover and are known to be geochemically anomalous above the buried ore and the variable geochemical dispersion processes affecting ore elements through the weathered profile. pSirogas studies indicate that the anomalies at the surface and the plume above the ore post-date formation of the palaeo-redox front and remained

active until mining (Johnston *et al.,* 1993; Rutherford, 2002c). The pSirogas measures gas and water vapour emissions from the ground and data collected by this method over Osborne are shown in Figure 3. This illustrates the character of geochemical profiles across the pit site for methods trialled.

Element dispersion patterns interpreted from 18 percussion holes across the Osborne ore zone (Figure 4) highlight the controls on element distribution through the weathered profile (Lawrance, 1996; 1999). These show a distinct anomaly 'plume' directly above the ore for a range of elements, the influence of palaeo-redox zones through the Mesozoic profile, and the present active redox zone at depth. There is a significant enrichment in major ore elements in the top 5 m of the profile, probably coincident with ferruginous upper mottled zone and duricrust. The leached saprolite beneath is poor in most elements, reflecting intense alteration during weathering.

Sampling of palaeo-redox zones, country rock and fractures transgressing upward through the pit walls, marginal to the mineralization, indicates that geochemical dispersion from the ore occurred preferentially through discrete sub-vertical fractures (Rutherford, 2000b). The best-expressed palaeo-redox zones within the Mesozoic are coincident with thin beds (about 100 mm) of pyrite-rich sediment within the sequence, now seen as massive concordant botryoidal hematite, with abundant alunite in the beds immediately above the sulphide-bearing horizon. The country rock and palaeo-redox zones only appear to host low-order anomalies close to the vertical fractures or where redox fronts intersect the ore. The compositions of the redox zones away from ore appears to reflect that of the Mesozoic sediments, with a local overprint imposed after the water-table had fallen to below the unconformity, and weathering and oxidation of the ore recommenced (Rutherford 2002b). Redox zones only become anomalous if they intersect mineralization or anomalous structures, such as fractures, extending from mineralization (Lawrance, 1996). This has implications for the use of shallow redox zone geochemistry as a regional indicator of mineralization beneath very thick cover. A dispersion halo from this is unlikely to be significant at the surface or in shallow palaeo-redox horizons until the present weathering and redox front has re-intersected the ore and active dispersion of ore elements has recommenced.

Reworking of anomalous redox horizons and fractures during duricrust formation, and subsequent surface and sub-surface hydromorphic dispersion, are thought to account for a broad secondary sub-surface halo in Cu and other ore elements away from the pit area (Rutherford, 2002a). In some locations, ferruginous horizons associated with zones of active silcrete development along drainages contain low but distinctive partial leach (Regoleach) ore signatures (Cu, Hg, Mo, Tl,
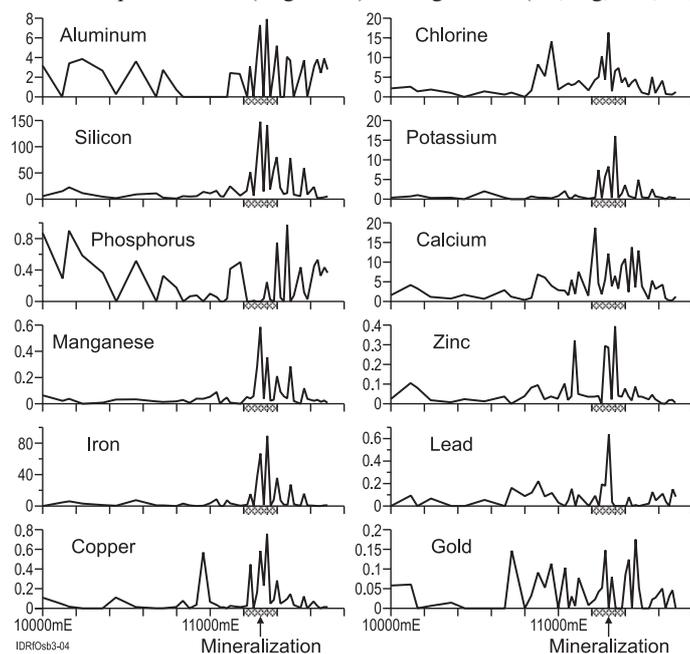
Figure 3. pSirogas profiles across the open pit area from 1992 survey. The mineralization is centred beneath 11200-11400mE. Mesozoic cover is approximately 30 m thick.
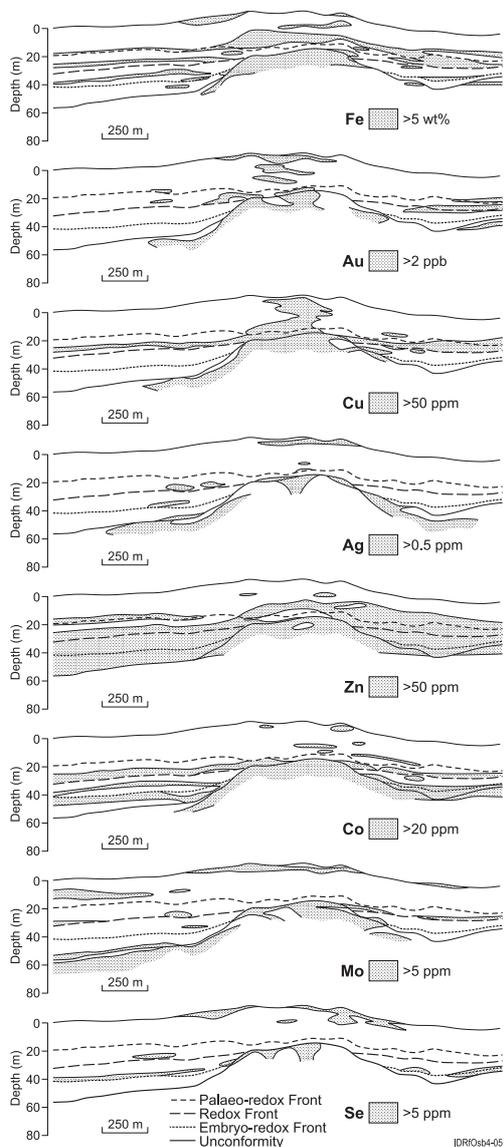
Figure 4. Distribution of Fe and selected elements through weathered profile.

Ag). At one locality, 1 km from the pit site, duricrust breccia beneath silcrete contains up to 140 ppm Cu. Low pH groundwaters (pH 4.2) in the vicinity of the mineralization may be contributing to these processes (Johnston *et al.,* 1993; Lawrance, 1993; 1996; 1999).

Figure legend items: Fe >5 wt%; Au >2 ppb; Cu >50 ppm; Ag >0.5 ppm; Zn >50 ppm; Co >20 ppm; Mo >5 ppm; Se >5 ppm. Palaeo-redox Front; Redox Front; Embryo-redox Front; Unconformity. IDRfOsb4-05

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SAMPLE MEDIA — SUMMARY TABLE

Sample medium	Indicator elements	Analytical method (Partial/Total)	Background range (ppm)[1]	Maximum anomaly (ppm)	Dispersion distance (m)[2]
Soil	Mn	0.1M HCl/ICP-AES	40-70	165	30V
	Fe	0.1M HCl/ICP-AES	2300-3000	13850	30V
	Co	0.1M HCl/ICP-AES	2-3	5.4	30V
	Cu	0.1M HCl/ICP-AES	2.5-3	86	30V/1000L
	Zn	0.1M HCl/ICP-MS	1-1.5	4.1	30V
	Se	0.1M HCl/ICP-MS	0.03-0.04	0.180	30V
	Mo	0.1M HCl/ICP-MS	0.002-0.003	0.075	30V/1000L
	Ag	0.1M HCl/ICP-MS	0.005-0.008	0.031	30V/1000L
	W	0.1M HCl/ICP-MS	0.003-0.004	0.015	30m V
	Hg	0.1M HCl/ICP-MS	0.003-0.007	0.100	30V/1000L
	Bi	0.1M HCl/ICP-MS	0.015-0.018	0.340	30V/1000L
Pit Wall	As	(Total) ICP-AES	4-10(C)	120(F)	30V
C=country	Cu	(Total) ICP-AES	50-75(C)	1000-2000(F)	30V
F=fracture	Ag	(Total) ICP-AES	0.050-0.075(C)	0.120-0.140(F)	30V
	Hg	(Total) ICP-AES	0.060-0.090(C)	0.160(F)	30V
	Co	(Total) ICP-AES	3-6(C)	53(F)	30V
	Mo	(Total) ICP-AES	0.001-0.004(C)	0.016(F)	30V
Pisoliths	Cu	Cold hydroxylamine	8.5	15-25	700
	Cu	Hot hydroxylamine	3.1	7-12	700

[1]The ranges for the pit wall compare the country rock above the ore zone with transgressive, sub-vertical ferruginous fractures that extend from the ore upward into the soil, through the weathered profile. They are not from horizontal palaeo-redox zones that may be locally similar near these fractures or generally less than those of the fractures depending on location in the pit. Data are a mix of partial, selective and total analyses.

[2]V = vertical; L = horizontal

All data are orientation data – exploration data unavailable.